Effect of Process Variables on Quality of Canned Tomato Juice[1]

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It is generally assumed that processes of food preservation cannot enhance the original raw-product quality. At best such procedures may be controlled in order to do the least possible harm to the quality of the raw material.

Of the factors involved in the quality of tomato products, color is the most important. In 1931 MacGillivray (7) stated that color loss in tomato juice increased as the processing temperature was increased. Kramer and Kattan (5) using a special heat exchange cell, found that in the range between 160 degrees F and 285 degrees F, color loss proceeded in accordance with the equation: Color loss = $\log \frac{\Sigma T}{525} \left(\frac{RT - 120}{40}\right)$ where color is in terms of the U. S. Dept. Agr. scoring system. T refers to second-degree F summations above 140 degrees F, and RT is the retort temperature. Kramer and Ogle (6), testing the above equation, found it to be valid under conditions similar to actual commercial procedures. The results obtained by the same authors also indicated that when equivalent sterilizing values were used, equal color losses resulted from the various sterilization temperatures, which is in agreement with previous finding by Blumer et al (1).

Murdock (8) has shown that citric acid has an inhibitory effect on tomato juice flat-sour organisms, thus opening the possibility of using lower sterilization values, providing the pH of the tomato juice was reduced. This can be accomplished either by the use of varieties naturally high in acidity, or by the addition of organic acids such as citric. Such reduced sterilization treatments would in turn reduce color loss, but may affect adversely the flavor factor of quality.

Other process variables that may affect canned tomato juice quality are finisher screen size, additives such as salt and sugar, and composition of the atmosphere in the can.

MATERIALS AND METHODS

The experiments under study were conducted during 1952, 1953, and 1954 as a part of a three-year research program concerning the improvement of quality of processed tomatoes and tomato products. The canning operations were varied according to the designs of the various experiments; otherwise, the following standard procedure was used. The tomatoes were washed, trimmed, and juiced in a miniature laboratory pulper and finisher, using a .028-inch screen. The juice was then heated in an open steam jacketed kettle to a closing temperature of 180 degrees F, canned in plain No. 1 cans and processed for 20 minutes at 212 degrees F. The procedures of the various quality determinations were described in a previous publication (4).

RESULTS AND DISCUSSION

I. Effect of Screen Size and Salting

The tomatoes used for this experiment were thoroughly mixed and one-third was pulped with a .035-inch screen, the second with a .028-inch screen and the third with a .021-inch screen. Each lot of juice was divided into two portions; one was salted with sodium chloride at the rate of 0.5 per cent, while the other was unsalted. Prior to processing, samples were taken from the various lots for determination of quality of the raw juice. Only the main effects of this experiment are presented in Table 1, since the interactions were not significant.

Table 1.—The main effects of screen size and salting on quality of raw and processed tomato juice.

Comparison	Color[a]	Viscosity[b]	pH	Soluble solids	Separation[c]	Total solids	Waste
					percentage		
Raw	30.2	14.0	4.40	5.5	—	—	—
Processed	26.7	11.8	4.39	5.9	—	—	—
L.S.D. 5%	0.3	0.7	N.S.	0.2	—	—	—
Plain	28.5	12.8	4.45	5.3	3.8	6.5	—
Salted	28.5	13.0	4.35	6.1	5.1	7.2	—
L.S.D. 5%	N.S.	N.S.	0.02	0.2	—	—	—
.021 inch screen	27.7	11.4	4.40	5.7	9.5	6.7	32.5
.028 inch screen	28.6	12.3	4.40	5.8	6.5	7.1	26.0
.035 inch screen	28.9	14.9	4.37	5.6	1.8	6.9	18.7
L.S.D 5%	0.4	0.9	0.03	N.S.	—	—	—

[a]As U.S. Grade equivalent.
[b]As seconds per 100 revolutions of Stormer viscosimeter.
[c]As clear supernatant serum.

The data in Table 1 indicated that the color score of the juice from the wide and medium screens was better than that of the juice from the fine screen. This was true in the raw and processed juice. Salting, however, did not exert any effect on color. The use of the fine screen also leads to more waste, and a greater yield of the clear yellowish serum, which separates out upon standing.

Viscosity decreased with processing, was not affected by salting, and progressively increased with the increase in the size of screen. It was consistently found that the effect of the screen size on viscosity was inversely related to the magnitude of separation of the clear serum. This separation was further increased by the addition of salt. These results may seem contrary to the findings of Kertesz (4), who reported that the separation of serum decreased as the particle size of the tissue was reduced. In the present study, however, micro-

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scopic examination of the various lots indicated that the juice fron the wider screens did not consist of uniformly large particles, bu rather of a mixture of small particles along with suspended shred of tissue, the amount of the latter increasing with the increase ir screen size. It may thus be postulated that if such sedimentation wa: due to the coagulating effect of heat application, these large piece of tissue would be less affected because of their relatively smallei exposed surface. The effect of salting could also be similarly ex plained as to its effect on the stability of the colloidal system.

It has been generally assumed that heat processing causes a reduction in pH of the tomato juice. It may be seen in Table 1 that this was actually due to the addition of salt and not to the process.

II. Effect of Can Atmosphere

It was reported by Cruess (2) that lycopene could be preserved indefinitely in carbon dioxide, nitrogen, or hydrogen. This experiment was primarily designed to study the influence of certain gases on the preservation of color in tomato juice. In order to magnify the effect of the various gases, within each gas treatment, the degree of fill was varied, namely, full, half full, or one-third full.

With the exception of the vacuum treatment, the juice was preheated to 180 degrees F. The juice was then placed in No. 1 cans and the specific gas was admitted to the can during the closing operation. This was accomplished by introducing the gas from the pressure cylinder into the vacuum chamber of the closing machine after evacuation of air. The various atmospheres under study were air, oxygen, vacuum, nitrogen, and carbon dioxide.

The data presented in Table 2 indicate that the gases had no effect on color when the cans were filled normally. With the exception of CO_2, decrease in fill was accompanied by a decrease in color and an increase in pH. This was most pronounced in the oxygen treatments. If the effects of the degree of fill were to be taken as an index for the efficiency of the various atmospheres, carbon dioxide would seem to be the most protective. The loss of color with the low fill could be attributed to greater heat application. It may be noticed in Table 2 that regardless of the gas treatment, color decreased as the fill was reduced. During processing, the juice in the cans with lower fill would be expected to reach the final temperature faster than the juice in a full can and thus would be receiving more heat units during the process which in turn would result in a higher color loss (5). In the presence of oxygen such color loss would be magnified as in the case of the oxygen and air treatments. The efficiency of vacuum and nitrogen was intermediate and was exceeded by the application of carbon dioxide. Repeated alternation of vacuum and gas, as suggested by Cruess (2), was not applied in this experiment and therefore complete evacuation of air was probably not attained before introducing the inert gases. Under these conditions the superior efficiency of CO_2 may be due to a higher rate of diffusion in the juice. Similar to these results were the effects on pH and percentage of total solids. The application of oxygen resulted in reduction of H-ion concentration and the percentage of total solids, while CO_2 again was the best protectant. The results presented in Table 2 also indicated that the non-preheated vacuum treatment reduced the viscosity of the processed juice and subsequently increased the separation of the clear serum.

Table 2.—Effect of atmospheres and fill on quality of processed tomato juice.

Gas	Fill	Color[a]	pH	Percentage of total solids	Viscosity[b]	Percentage of separation[c]
Air	Full	25.9	4.29	6.6	10.8	1.4
	2/3	25.7	4.31	6.7	11.0	1.5
	1/3	24.2	4.33	6.6	10.8	1.4
Oxygen	Full	25.7	4.35	6.0	10.9	0.8
	2/3	24.9	4.37	6.0	11.0	1.6
	1/3	23.9	4.51	6.1	11.0	1.2
Vacuum	Full	26.0	4.30	6.8	9.8	2.2
	2/3	25.6	4.30	6.9	9.5	3.3
	1/3	24.9	4.32	6.9	9.9	2.8
Nitrogen	Full	26.0	4.29	6.7	10.8	1.4
	2/3	25.9	4.30	6.5	10.9	1.3
	1/3	24.8	4.33	6.9	11.0	1.4
Co_2	Full	26.0	4.30	6.9	10.9	1.5
	2/3	25.8	4.30	6.9	10.6	2.0
	1/3	25.5	4.30	7.0	11.2	1.5
L.S.D. 5%		0.8	0.02	0.4	0.5	0.7

[a] As U.S. Grade Equivalent.
[b] As seconds per 100 revolutions of Stormer viscosimeter.
[c] As clear supernatant serum.

III. Relationship Between pH and Heat Sterilization

It was previously reported (1, 5) that the use of various sterilization temperatures did not affect the color of the processed juice providing the comparisons were made on basis of equal sterilization value (F_0) of 0.7. It was the objective of this study to investigate the possibility of lowering the sterilization requirements by reducing the pH of the juice.

In a preliminary experiment the pH of the raw juice was adjusted to 3.4, 3.8, 4.0, 4.4, 4.7, and 5.0, by means of citric acid and sodium hydroxide. The juice was preheated to 160 degrees F, filled in No. 1 cans and processed at one of three temperatures: 160, 190, or 212 degrees F. With each of the three temperatures three different durations were used which also varied according to the pH of the juice. At pH 3.4 and 3.8 processing time was 4, 12, and 36 minutes; 6, 18, 54 minutes at pH 4.0 and 4.4; and 8, 27, 72 minutes at pH 4.7 and 5.0.

The data presented in Table 3 indicated that when the pH of the juice was adjusted to 4.0 or below, no spoilage occurred in any of the processing treatments. As the pH increased, the minimum heat sterilization requirement increased progressively. Although pH differences in this experiment were too large for practical use, the findings appeared to be promising and justify more work along this line.

Accordingly, a factorial experiment was designed to investigate

Table 3.—Effect of pH and heat sterilization on keeping quality of processed tomato juice.

Process		pH					
Temperature	Time[b]	3.4	3.8	4.0	4.4	4.7	5.0
212°F	Long	*[a]	*	*	*	*	*
	Medium	*	*	*	*	*	–
	Short	*	*	*	–[a]	–	–
190°F	Long	*	*	*	*	*	–
	Medium	*	*	*	–	–	–
	Short	*	*	*	–	–	–
160°F	Long	*	*	*	–	–	–
	Medium	*	*	*	–	–	–
	Short	*	*	*	–	–	–
Processing minutes........		4, 12, 36		6, 18, 54		8, 24, 72	

[a] * signifies good – signifies spoiled

further the effects of the pH and the sterilization treatments on the quality of the processed juice. The variables involved in the factorial were: sanitation, pH, method of pH adjustment, sterilization treatment, and inoculation with *Bacillus thermoacidurans.* In order to simulate good and poor sanitation conditions, the tomatoes were thoroughly mixed and divided into two lots; in one lot the fruits were individually washed and trimmed before pulping while in the other lot the fruits were washed in bulk and not trimmed. The pH of the juice was adjusted to 4.0, 4.2, 4.4, or 4.6. This adjustment was accomplished either organically with citric acid and sodium citrate or inorganically with HCl and NaOH in order to study the effects of pH and the citrate ion separately (8). Sterilization treatments were 15, 30, and 45 minutes at 190 degrees F; 10, 20 and 30 minutes at 212 degrees F; and 5, 10 and 15 minutes at 230 degrees F. In one half of the experiment the cans were inoculated with spore suspensions of *B. thermoacidurans* according to the method suggested in a personal communication by E. J. Cameron of the National Canners Association, whereas the other half was not inoculated. All treatments were conducted in triplicate, making a total of 864 samples.

The results presented in Table 4 indicated that the color of the processed juice was not affected by pH adjustment but was significantly influenced by the sterilization treatments regardless of pH. If sterilization at 212 degrees F for 20 minutes may be considered as standard, it could be seen that the use of 190 degrees F for 15, 30, and 45 minutes; 212 degrees F for 10 minutes; and 230 degrees F for 5 minutes resulted in a reduction of color loss. It is interesting that with a raw product of poor color (27.4), such as that used in this study, the standard treatment of 20 minutes at 212 degrees F resulted in a standard grade of processed juice, while the use of 10 minutes at 212 degrees F or 15 minutes at 190 degrees F resulted in a fancy finished product.

The samples obtained from this study were stored at room temperature for a period of four months, during which all swells were recorded and discarded. At the end of storage all samples were examined for development of flat-sour, and the data are presented

Table 4.—Effect of pH and sterilization temperature and time on color of tomato juice (U. S. color score for raw product: 27.4).

Temperature	Time (minutes)	pH 4.0	pH 4.2	pH 4.4	pH 4.6	Average	Color loss
190°F	15	25.9	25.8	25.9	26.2	25.9	1.5
	30	25.2	25.4	25.6	25.6	25.4	2.0
	45	25.1	25.4	25.1	25.2	25.2	2.2
212°F	10	25.8	25.4	25.5	25.6	25.6	1.8
	20	24.7	24.7	24.9	24.8	24.8	2.6
	30	24.3	24.0	23.8	24.1	24.0	3.4
230°F	5	25.2	25.2	25.1	25.3	25.2	2.2
	10	24.6	24.0	24.7	24.6	24.5	2.9
	15	24.2	24.2	24.1	24.1	24.1	3.3
Average..............		25.0	24.9	25.0	25.0	L.S.D. 5%	0.3

in Table 5. Since the effects of inoculation and method of pH adjustment were found to be insignificant, each datum in Table 5 represents the number of cans swelling and/or developing flat-sour out of a total of 12 cans. In analyzing the data no effort was made to separate swelling from flat-sour, because of the obvious possibility of having the two combined in the swells.

In this study, inoculation did not seem to have any effect, possibly because of the presence of the bacteria in the raw product. It was reported by Murdock (8) that within the same pH levels citric acid was more inhibitory to growth of *B. thermoacidurans* than was HCl. Although a very slight trend in this direction was found in the present study, the difference was too small to be of any statistical significance. The work of Murdock, however, was done with artificial media in contrast with the experiments reported in this study, where tomato juice was used.

The results obtained in this study were certainly indicative of the

Table 5.—Effects of sanitation and processing on number of cans developing swelling and/or flat-sour after four months of storage at room temperature.

Sanitation	pH	Processed at 190°F, Minutes 15	30	45	Processed at 212°F, Minutes 10	20	30	Processed at 230°F, Minutes 5	10	15	Sanit. x pH
Good........	4.0	1	0	0	1	0	0	2	0	1	5
	4.2	1	0	1	1	1	0	1	1	0	6
	4.4	4	1	0	1	1	0	1	2	0	10
	4.6	6	2	2	3	1	0	4	1	0	19
Total.........		12	3	3	6	3	0	8	4	1	
Poor........	4.0	0	0	1	0	1	0	0	0	0	2
	4.2	4	3	0	8	0	0	0	2	0	17
	4.4	12	12	12	12	8	0	7	7	1	71
	4.6	12	12	12	12	12	2	12	12	2	88
Total.........		28	27	25	32	21	2	19	21	3	
Grand total...		40	30	28	38	24	2	27	25	4	

L.S.D. 5%:	
Sanitation	21.0
pH	14.8
Process	9.9
Sanitation x pH	10.5
Sanitation x process	7.1
pH x process	4.9
Sanitation x pH x processing	3.6

Insignificant effects:		
Inoculation:	inoculated	109
	not inoculated	109
H Adjustment:	organic	102
	inorganic	116

relationship between the pH of the tomato juice and the thermal sterilization requirement. It seems that tomato juice at lower pH levels could be safely sterilized with fewer heat units, resulting in a finished product of superior color. Reduction in pH could be achieved by breeding (3) or by means of addition of citric acid, which is the major naturally-occurring organic acid in tomatoes. Previous studies (3) indicated that flavor was not affected by varietal differences in pH even with levels as low as 4.19. In the present study a limited amount of work was conducted to investigate the reaction of taste panels to the palatability of the juice as affected by the citric acid alteration. In one test the juice was salted and the pH was adjusted to 4.3, 4.2, 4.1, 4.0, and 3.9 and the following sensory rating was used: +2 = flat, +1 = slightly flat, 0 = perfect, −1 = slightly tart, −2 = tart.

The following data show the reaction of the panel:

pH of juice	*Flavor rating*
3.9	−1.4
4.0	−0.7
4.1	−0.3
4.2	+0.3
4.3	+0.7

It was thus indicated that when the pH was reduced from 4.3 to 4.0, the flavor remained within acceptable limits. In another test the pH was adjusted by citric acid or sodium citrate, to eight different levels ranging between 3.9 and 4.6. The juice was canned plain, with 0.5 per cent salt, with 0.5 per cent sugar, or with 0.25 per cent salt + 0.25 per cent sugar. The panel members did not accept the taste of the juice when canned plain or when sugar alone was added, and scored both of them extremely low. Accordingly the flavor data presented in Table 6 are devoted to salted juice and to the salt and sugar combinations, using a rating system of 1–10, with 10 indicating the best flavor.

In this test the natural pH of the raw juice was 4.42, which is an average pH value for mid-season tomatoes in the tri-state area of Maryland, Delaware and Virginia (3). When comparing the flavor scores of the other pH levels with the pH of 4.42, it was found that where salt alone was added, the score started to decrease significantly

Table 6.—Effect of pH, salt, and sugar on palatability of processed tomato juice.

pH raw	pH of processed juice				Flavor rating[a]	
	Plain	Salt	Sugar	Salt and sugar	Salt	Salt and sugar
3.94	3.99	3.93	4.00	3.92	4.5	4.7
4.04	4.09	4.02	4.10	4.00	4.0	4.8
4.08	4.13	4.03	4.11	4.02	5.6	6.0
4.24	4.26	4.19	2.27	4.19	5.7	6.4
4.33	4.35	4.27	4.36	4.26	7.1	7.7
4.42	4.44	4.33	4.46	4.36	7.5	7.4
4.48	4.51	4.44	4.51	4.40	7.6	7.8
4.56	4.61	4.47	4.60	4.51	7.4	7.3
					L.S.D. 5%	1.6

[a]Rating on scale of 1 (poorest) to 10 (best).

at pH 4.24, whereas when both sugar and salt were added, the score did not drop significantly except when a pH of 4.04 was reached. It was also found that the panel, in general, preferred the juice with sugar and salt. Flavor in tomato juice thus is not a mere function of pH, but rather of sugar-acid ratio, as may be indicated from the data in Table 6 where the pH of the salted, processed juice was not different from that of the juice with salt and sugar.

The results obtained from these various tests are by no means indicative of immediate practical recommendations, but certainly promising for the possibility of adjusting the sterilization values according to the acidity of the juice, be it natural or by alteration of pH. The consumers' acceptance of high-acid juice should be the objective of more detailed studies, and if and when reached, the ultimate result will be a processed juice of superior quality. The curves in Fig. 1 show the amount of citric acid necessary for reduc-

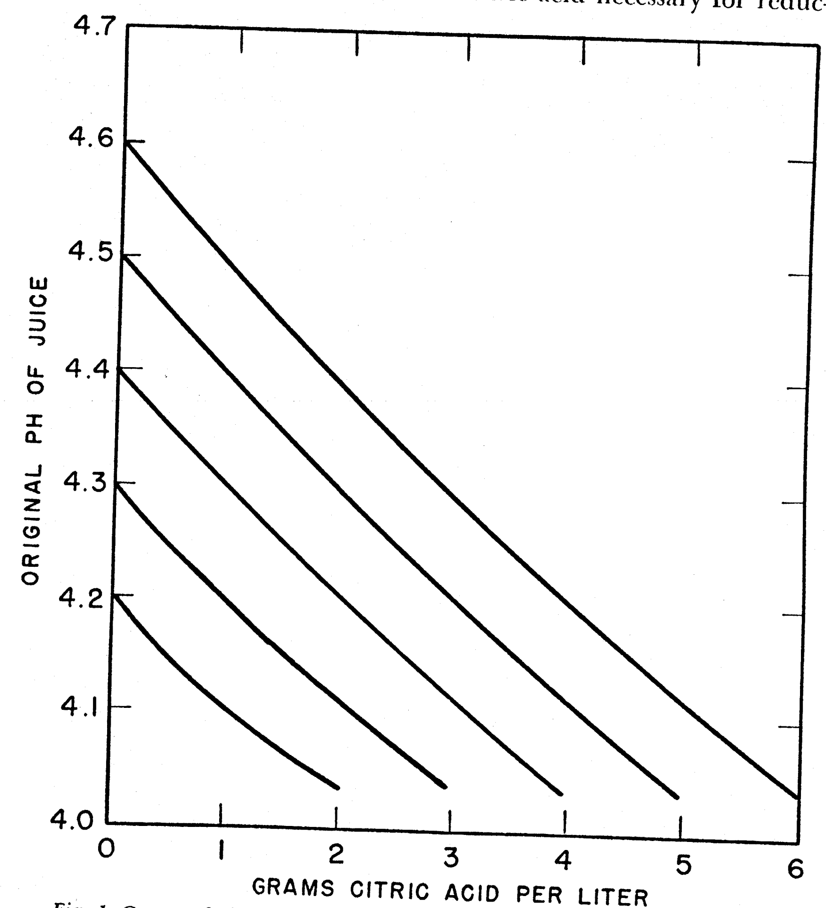

Fig. 1. Grams of citric acid per liter of tomato juice required to reduce the pH of the original juice to a given pH.

tion of pH. These data were compiled from the numerous buffer-action curves which were determined throughout the course of this study.

IV. Effect of Processing Treatments in Relation to Storage Temperature and Duration

It has been pointed out that during the course of the three-year study, some of the various processing treatments under investigation proved promising when studied separately. It was therefore the objective of this experiment to examine the effects of these treatments when combined factorially and as affected by storage temperature and duration. The quality determinations were made after two, three, and four months of storage at either room temperature or 35 degrees F. Variables under study other than storage were screen size, gas, and process. Two screen sizes were used, .021 inch and 0.35 inch. The two gases used were air and CO_2. The application of CO_2 was accomplished by letting the gas seep into the juice through a porous porcelain filter for fine dispersion. This was applied to the cold juice immediately after pulping and again to the preheated juice in the cans before closing. Two processes were used: in one treatment the pH of juice was adjusted to 4.0 by citric acid and the juice sterilized for 10 minutes at 212 degrees F, whereas in the other the pH was not altered and the juice was sterilized for 20 minutes at 212 degrees F. The entire experiment was conducted in triplicate, resulting in a $3 \times 3 \times 24$ factorial with a total of 144 samples. The effects on color, ascorbic acid content, soluble solids percentage, and pH are presented in Table 7. The raw juice in this study had an average color score of 27.6 and contained 6.27 per cent soluble solids. Ascorbic acid was determined by the dichlorophenolindophenol dye titration method.

The results presented in Table 7 indicated that color was affected by screen size and by process. The lower pH and sterilization treatment resulted in a fancy-grade color as compared with a low standard color of the check treatment. The color was also better with the large screen than with the fine screen. This effect of screen was more pronounced with the high pH and sterilization, as may be indicated by the process $\times$ screen-size interaction. These results were in accord with the earlier findings reported in this study. The use of CO_2 did not improve the color of the finished product; however, this was also true in the can atmosphere studies when the cans were completely filled with juice. Contradicting what is believed in the industry, color was not improved by storage duration or temperature, which is in agreement with the results obtained by Blumer *et al* (1).

It has been reported by Scott and Walls (9) that ascorbic acid in tomato juice decreases upon storage at 70 degrees F. The results of the present study show that refrigeration at 35 degrees F resulted in higher ascorbic acid retention as compared with room temperature. The ascorbic acid content decreased upon storage at room temperature, whereas at 35 degrees F it remained constant, as may be seen in the interaction of storage $\times$ storage temperature. The use of CO_2 resulted in higher retention of ascorbic acid during storage which seems to be similar to its protecting effect on color, pH, and soluble solids, as was shown in Table 2. It appears that ascorbic acid losses during storage are, in some manner, related to the oxidation-reduction mechanism that accompanies the detinning reactions (3) in the can, which may explain the protective effect of CO_2.

Table 7.—Effect of several processing treatments and storage duration on quality of tomato juice.

Variable	Treatment	Color, U.S grade equivalent	Ascorbic acid mgm/100 gms.	Soluble solids (per cent)	pH
Screen size	1 small .021 in.	24.1	23.8	6.26	4.22
	1 large .035 in.	24.6	24.6	6.26	4.22
	L.S.D. 5%	0.2	0.3	n.s.	n.s.
Gas	Air	24.4	23.9	6.28	4.21
	CO_2	24.3	24.4	6.24	4.22
	L.S.D. 5%	n.s.	0.3	n.s.	n.s.
Process	pH 4.0 10m/212°F	25.6	23.6	6.45	3.98
	pH 4.5 20m/212°F	23.1	24.7	6.07	4.45
	L.S.D. 5%	0.2	0.3	0.06	0.01
Storage Duration	2 months	24.4	24.3	6.32	4.24
	3 months	24.4	24.1	6.30	4.20
	4 months.	24.3	24.1	6.16	4.21
	L.S.D. 5%	n.s.	n.s.	0.08	0.02
Storage Temperature	room temperature	24.4	23.4	6.32	4.22
	35°F	24.3	24.9	6.20	4.21
	L.S.D. 5%	n.s.	0.3	0.06	n.s.
Process x Screen size	pH 4.0—small	25.5	23.0	6.46	3.99
	pH 4.0—large	25.7	24.1	6.44	3.97
	pH 4.5—small	22.8	24.5	6.06	4.44
	pH 4.5—large	23.4	25.0	6.07	4.46
	L.S.D. 5%	0.3	0.4	n.s.	n.s.
Storage Duration x Storage Temperature	2 mo.—room	24.4	23.8	6.39	4.25
	3 mo.—room	24.4	23.3	6.35	4.20
	4 mo.—room	24.4	23.1	6.21	4.21
	2 mo.—35°F	24.3	24.8	6.24	4.23
	3 mo.—35°F	24.3	24.8	6.25	4.19
	4 mo.—35°F	24.2	25.1	6.11	4.20
	L.S.D. 5%	n.s.	0.5	n.s.	n.s.

The use of the .035-inch screen resulted in higher ascorbic acid than the .021-inch screen, which seemed to be primarily a result of oxidation, as was explained earlier in this study under the effect of screen size. The use of the fine screen or the reduction of the particle size would enhance oxidation because of the relatively large surface exposed to air and metal. It was of interest to notice that ascorbic acid was consistently lower when the pH was reduced to 4.0 and the juice sterilized for 10 minutes at 212 degrees F, and that this reaction was magnified by the use of the fine screen. Such an effect obviously contradicts the literature and cannot be true. The only explanation here would be that pH adjustment with citric acid was done in open pans and that the effect obtained here was due to the excessive oxidation that accompanied the continuous stirring involved in this operation. Undoubtedly, such effect would not have appeared had the mixing been accomplished under air-free conditions.

Among all the variables of this experiment, storage duration and temperature were the only factors influencing the percentage of soluble solids. It was previously found by Scott and Walls (9) that the sugar content of tomato juice decreases with storage. This seems to be in agreement with the results obtained at the present study. At both storage temperatures the percentage of soluble solids progressively decreased with the duration of storage and at each storage period the juice stored at room temperature contained a higher percentage of soluble solids that that in the juice under refrigeration. Also, in agreement with the same workers it was found that the pH of the juice decreased with storage. This trend was not affected by any of the variables in this study.

Summary and Conclusion

The objectives of this study were to examine the effects of the various processing operations on the quality of the canned tomato juice, and to investigate the possibilities of modifying these operations in order to obtain maximum quality retention. The work was conducted during 1952, 1953, and 1954 and the following conclusions may be stated.

Increasing the size of the screen openings of the juice finisher was found to increase the retention of color and ascorbic acid, minimize the separation of the clear serum, and significantly reduce the percentage of waste.

Salting resulted in reduction of the pH of the processed juice and increased separation. In the past, the reduction in pH has been frequently attributed to heat processing.

The application of CO_2 as a can atmosphere was of no practical significance; however, under conditions of potentially high oxidation (Table 2) it resulted in high retention of color, pH, and total solids. CO_2 also improved the retention of ascorbic acid.

Heat application was the most important factor involved in loss of color during processing. This study indicated that the thermal sterilization value could be safely reduced by pH adjustment with citric acid, providing proper sanitary conditions accompany the production of fancy juice. Such pH alteration, if proved to be accepted by the consumer, could significantly improve the grade of the canned juice.

Color of the canned juice was not affected by storage duration or temperature. Ascorbic acid decreased during storage at room temperature. Such decrease was prevented by storage at 35 degrees F. Soluble solids and pH both decreased during storage regardless of temperature.

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